Section IV. REMARKS

The pending claims in the application are claims 1, 3-7, 10-13, 16 and 19.

Amendment of the Specification, Addition of New Figures, and Submission of the Affidavit Regarding Amendatory Material

The specification has been amended to include the limitations of the originally filed claims, said limitations having also been disclosed in U.S. Patent Nos. 5,593,580 and 5,868,930, the contents of which were expressly incorporated by reference in the instant specification, at page 13, lines 14-15 thereof.

In addition, three new figures have been added herein (Figures 13, 13A and 14), consistent with the originally filed claims, and U.S. Patent No. 5,868,930, the contents of which were expressly incorporated by reference in the instant specification, at page 13, lines 14-15 thereof.

Applicant has submitted an affidavit, contained in **Exhibit 1** hereof, attesting to the fact that the amendatory material introduced herein in the specification and drawings of the instant application is subject matter disclosed by U.S. Patent No. 5,868,930, that the disclosure of U.S. Patent No. 5,868,930 is incorporated by reference in the present application and that no new matter has been added within the meaning of 35 U.S.C. §132(a).

Rejection of Claims 1, 3-8, 10-13, 16 and 19, and Traversal Thereof

In the January 21, 2004 Office Action:

claims 1, 3-7, 10-13, 16 and 19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Kopf `930 (U.S. Patent No. 5,868,930) in view of Demmer et al. (U.S. Patent No. 5,618,418) or Karbachsch et al. (U.S. Patent No. 5,225,080).

These rejections, based on Kopf '930 in view of Demmer et al., or alternatively on Kopf '930 in view of Karbachsch et al., are traversed and reconsideration of the patentability of the claims is requested in light of the following remarks.

§103(a) Rejection of Claims 1, 3-7, 10-13, 16 and 19 over Kopf `930 in view of Demmer et al.

Applicant traverses the rejection in the January 21, 2004 Office Action of claims 1, 3-7, 10-13, 16 and 19 based on Kopf `930 (U.S. Patent No. 5,868,930) in view of Demmer et al. (U.S. Patent No. 5,618,418) (hereinafter Demmer).

Kopf `930 relates generally to a cross-flow filtration unit comprising a multiplicity of stacked filtration cassettes, wherein the stacked filtration cassettes comprise membrane filter sheets arranged in a multilaminate, peripherally bonded array, and wherein the membrane filter sheets are alternated with foraminous permeate sheet elements and ribbed retentate channel elements.

Demmer relates to a dead-end filtration unit for the selective separation of fluid substances with porous membrane adsorbers.

The Examiner has contended that Kopf `930 discloses all of the details of claim 1, including thin gasket layers, but fails to specify the gasket as being bonded to the top and bottom surfaces of the cassette and bonded to and fully encapsulating the side surfaces of the cassette. The Examiner has further stated that Demmer discloses at least one thin gasket layer bonded and fully encapsulating all outer surfaces of the cassette. As such, the Examiner has concluded that:

> "it would have been obvious to have modified the cassette of Kopf so as to have included a thin gasket layer bonded to and fully encapsulating all outer surfaces of the cassette . . . as suggested by Demmer et al. . . . ."

Applicant vigorously disagrees.

When performing an obviousness evaluation, it is incumbent upon the Examiner to consider the inventions of the cited references in their entireties. *See*, *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 220 U.S.P.Q. 303 (Fed. Cir. 1993), *cert. denied*, 469 U.S. 851 (1984). Certain individual features from the references may not be chosen and merely lumped together as a mosaic in an attempt to meet the features of the rejected claims, while arbitrarily ignoring other teachings disclosed in the references. This legal concept is important for the Examiner to remember when attempting to combine prior art that teaches entirely different methodologies using entirely different structures.

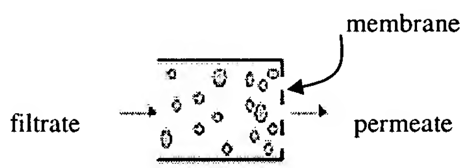
Further, to establish a *prima facie* case of obviousness based on a combination of the content of various references, there must be some teaching, suggestion or motivation in the prior art to make the specific combination that was made by the applicant. *In re Dance*, 160 F.3d 1339, 1342 (Fed. Cir. 1998); *In re Oetiker*, 977 F.2d 1443, 1445, 24 USPQ2d 1443, 1445 (Fed.Cir.1992).

As discussed hereinabove, Kopf `930 teaches cross-flow filtration units comprising a multiplicity of stacked filtration cassettes. In contrast, Demmer teaches dead-end filtration units.

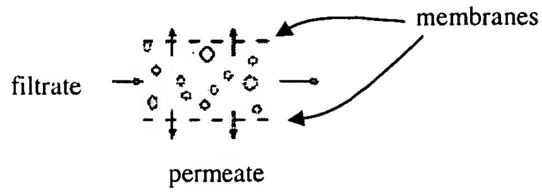
It is well known in the art of membrane technology that there are two fundamentally different membrane filtration systems – **dead-end filtration and cross-flow filtration** - having entirely different configurations and different energy requirements.

Referring to **Appendices B-E** attached herein,[1] four references are provided that demonstrate the differences between these two fundamental categories of filtration methodologies.

Briefly, during **dead-end filtration**, all of the water that enters the membrane surface passes through the membrane. However, the flux through the membrane decreases with time because solids are captured by the membrane as the water flows through it. Eventually, filtration must be terminated so that the membrane can be cleaned. A schematic of a dead-end filter is shown below.



In contrast, during **cross-flow filtration**, the filtrate is delivered tangentially to the membrane as turbulently as possible in order to constantly clear the membrane layer by rinsing, thus counteracting the formation of a captured layer of solids at the pores of the membrane. Unlike dead-end filtration, a stable flux through the membrane can be achieved because of the reduced build-up of captured species at the membrane surface. A schematic of a cross-flow filter is shown below.



Considering Kopf `930 and Demmer as a whole, the two references teach fundamentally different filtration structures and methodologies. Applicant questions which principle of filtration the Examiner proposes to be used in combining the cited references, **dead-end filtration**, as taught by Demmer, **cross-flow filtration**, as taught by Kopf `930, or a combination of the two?

In this respect, it is to be noted that Kopf `930 teaches away from a filtration unit that utilizes both cross-flow and dead-end filtration.

Referring to the Description of the Related Art, Kopf `930 addresses the **disadvantages** of prior art filtration systems that are partially utilized in cross-flow and partially in dead-end filtration. According to Kopf `930,

> "[w]hen the solids in the central portion have been built up to a point requiring backwashing or cleaning of the filter, only that portion of the filter utilized in cross-flow can be cleaned. The peripheral areas of the filter sheet [i.e., the dead-end portion of the filter] remain fouled and cause carryover of fouled material from one batch process to the next." (see Kopf `930, col. 2, lines 30-40)

As such, Kopf `930 teaches away from the combination of a cross-flow filtration and a dead-end filtration unit.

Thus, Kopf `930 teaches away from the dead-end filtration unit of Demmer.

The Examiner is respectfully reminded that it is improper to combine references when the references teach away from their combination. *See*, *e.g.*, *In re Grasselli*, 218 U.S.P.Q. 769, 779 (Fed. Cir. 1983).

[1] See: http://www.lenntech.com/membrane-systems-management.htm (**Appendix B**); http://www.dksepsys.dk/university.htm (**Appendix C**); http://www.pwea.org/Images/lin.pdf (**Appendix D**); and http://www.uow.edu.au/wng/crsematl/dharma/reuse/week10/tutor10.htm (**Appendix E**); respectively.

Furthermore, in light of the Description of the Related Art in the Kopf `930 reference, one skilled in the art would not reasonably expect that the combination of the cross-flow filtration unit of Kopf `930 and the dead-end filtration unit of Demmer, would result in a successful filtration apparatus or method.

The Examiner is respectfully reminded that a *prima facie* case of obviousness based on a combination of various references is established only when there is some teaching, suggestion or motivation <u>in the prior art references themselves</u> to make the specific combination that was made by the applicant. *See, e.g., In re Lee*, 61 U.S.P.Q.2d 1430, 1433 (Fed. Cir. 2002).

In the present case, the Examiner indicated that "it would have been obvious to have modified the cassette of Kopf . . . ." (see the Office Actions dated October 9, 2002, March 26, 2003, August 13, 2003 and the present Office Action) without identifying any motivation or teaching <u>in the cited references themselves</u> to make the specific combination. *Id.*

Where is the objective evidence showing motivation or teaching <u>in the references themselves</u> to make the combination of Kopf '930 and Demmer that has been hypothesized by the Examiner? As stated by the court in *In re Dance*, 48 U.S.P.Q.2d 1635, 1637 (Fed. Cir. 1998):

> "[o]ur case law makes clear that the best defense against the subtle but powerful attraction of a hindsight-based obviousness analysis <u>is rigorous application of the requirement for a showing of the teaching or motivation to combine prior art references</u>." (emphasis added)

As an aside, for the record, the Examiner stated in the January 21, 2004 Office Action that:

> "[w]ith respect to claim 19, Kopf [`930] discloses all of the details of claim 19 including thin gasket layers positioned adjacent to main top and bottom surfaces of the filtration cassette, wherein the thin gasket layer comprises an elastic material for forming a fluid tight seal between the filtration cassette and adjacent structure engaged therewith, <u>the gasket assembly fully encapsulating the filtration cassette</u>, and the gasket layers encapsulating main top and bottom surfaces of the filtration cassette except for the inlet basin, outlet basin, and permeate passage openings." (see January 21, 2004 Office Action, page 4, lines 9-15) (emphasis added)

Applicant vigorously disagrees with the Examiner's interpretation of what Kopf `930 discloses.

Specifically, with regard to claim 1, the Examiner admitted that Kopf `930 "**fails** to specify the gasket as being . . . bonded to and fully encapsulating the side surfaces of the cassette" (see January 21, 2004 Office Action, page 2, lines 19-21), however with regard to claim 19, the Examiner stated that Kopf `930 **discloses** "the gasket assembly fully encapsulating the filtration cassette" (see January 21, 2004 Office Action, page 4, lines 12-13).

Applicant requests that the Examiner correct this inconsistency by formally acknowledging that Kopf `930 fails to teach a gasket assembly fully encapsulating the filtration cassette, as the Examiner has expressly admitted with regard to claim 1.

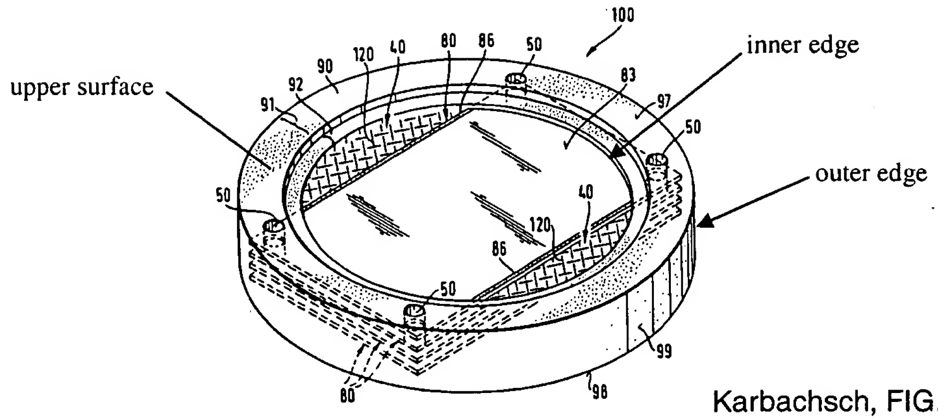
Upon such correction of the record, the Examiner is respectfully requested to withdraw the rejection of claims 1, 3-7, 10-13, 16 and 19 under 35 U.S.C. §103(a) based on Kopf `930 in view of Demmer, since (1) there is no motivation, suggestion or basis in Kopf `930 or Demmer for their combination, (2) there is no reasonable expectation of success in any attempt to make a combination of teachings of such references, and (3) Kopf `930 teaches away from Demmer, and there is therefore no proper basis for §103(a) rejection.

§103(a) Rejection of Claims 1, 3-7, 10-13, 16 and 19 over Kopf `930 in view of Karbachsch et al.

In the January 21, 2004 Office Action, claims 1, 3-7, 10-13, 16 and 19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Kopf `930 (U.S. Patent No. 5,868,930) in view of Karbachsch et al. (U.S. Patent No. 5,225,080) (hereinafter Karbachsch).

Applicants traverse such rejection.

Karbachsch teaches a filtration module **100** wherein at least two multilayer filter units **80** are stacked on top of one another, separated by a spacer **120**, and are connected in a leakproof manner by means of an annularly-shaped edge seal **90**. A plurality of filtration modules **100** can be stacked upon one another and compressed together in a casing to form a filtration device. Karbachsch's filtration module, as shown in Figure 11a of such reference, is reproduced below.



Karbachsch, FIG. 11a

The annularly-shaped edge seal (also referred to as the sealing material ring), of Karbachsch is a ring comprising an upper surface, a lower surface and an outer and inner edge. According to Karbachsch, the annular sealing material fulfills various functions, including:

> "by its inner edge surfaces defines the unfiltered material channel [40] and the filter unit [80] stacks. Furthermore the sealing ring is preferably constructed in such a width, i.e. the distance between the inner edge surface and the outer edge surface is sufficiently large such that the sealing material ring can accommodate at least one filtrate channel [50] **of a sufficiently large diameter**. For example the diameter used for a filtrate channel is frequently approximately 5 to 6 mm and the sealing ring is generally approximately 2 cm wide and also approximately 2 cm high. In the case of large modules height and width may be as much as 5 cm." (see Karbachsch, col. 6, lines 26-42) (emphasis added)

Under normal operating conditions, the Karbachsch filtration module experiences pressure in the range of 4 to 5 bars (approximately 4 to 5 atm) (see Karbachsch, col. 7, lines 12-13).

The Examiner has asserted that Kopf `930 discloses all of the details of claim 1 including thin gasket layers, but fails to specify the gasket as being bonded to the top and bottom surfaces of the cassette and bonded to and fully encapsulating the side surfaces of the cassette. The Examiner has further contended that Karbachsch discloses at least one thin gasket layer bonded to and fully encapsulating all outer surfaces of the cassette, and concluded that

> "it would have been obvious to have modified the cassette of Kopf so as to have included a thin gasket layer bonded to and fully encapsulating all outer surfaces of the cassette . . . as suggested by Karbachsch et al. . . . ."

Applicant vigorously disagrees.

As discussed hereinabove, the Examiner is not allowed to focus on specific elements of the cited references and rearrange them to yield applicant's claimed invention, while simultaneously (and arbitrarily) disregarding other relevant teachings of the cited references. In the present case, this is exactly what the Examiner has done – extracted elements from Kopf `930 and Karbachsch to construct applicant's claimed invention in light of applicant's own disclosure. This approach is legally improper.

In fact, if the teachings of Kopf `930 and Karbachsch were to be combined, as hypothesized by the Examiner, Kopf `930 by such modification would be rendered unsatisfactory for its intended purpose, and as such, a *prima facie*, case of obviousness has not been established. *See*, *In re Gordon*, 221 U.S.P.Q. 1125 (Fed. Cir. 1984).

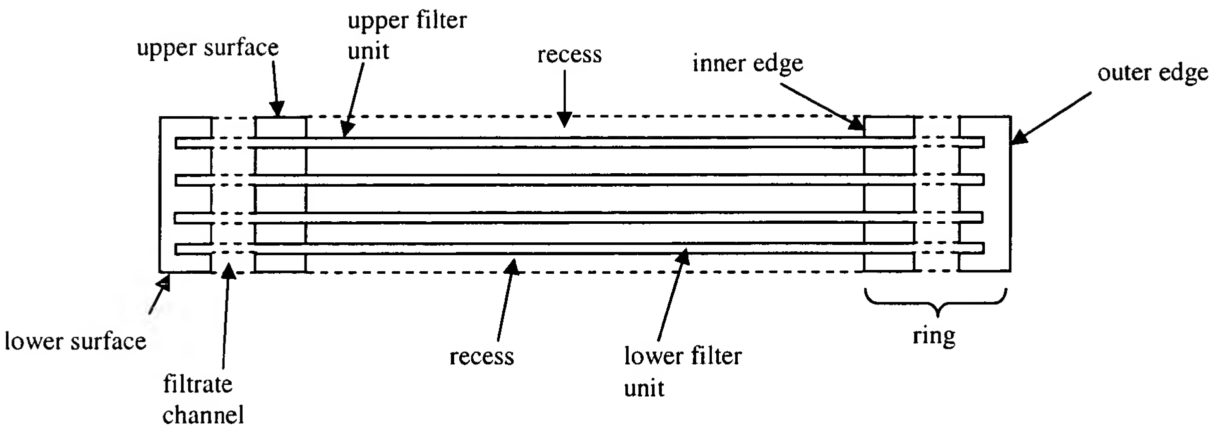
The Examiner is respectfully reminded that the <u>teaching of Karbachsch must be considered for all that it entails</u>.

In the present case, the Examiner has chosen to import the encapsulating ring of Karbachsch into the teaching of Kopf `930.

Interestingly, the Examiner chose to import only the outer edge of the Karbachsch ring, effectively ignoring the upper surface, lower surface and most importantly, inner edge of the Karbachsch ring.

The inner edge of the Karbachsch ring defines the unfiltered material channels **40** of the Karbachsch filtration module (see Figure 11a of Karbachsch hereinabove)

Because the upper surface and lower surface of the Karbachsch ring are on different planes than the upper filter unit **80** and lower filter unit **80**, respectively, there is a recess in the center of the Karbachsch module (wherein the recess is defined by the circumferential sealing ring), as shown below in the schematic of a cross-section of the Figure 11a Karbachsch module[2] (wherein the module is bisected at the filtrate channels **50** in Figure 11a of Karbachsch shown hereinabove).



If the Examiner is suggesting that the encapsulating ring of Karbachsch be imported into the cassette of Kopf `930, the Examiner must import the whole ring, NOT just the outer edge of the ring.

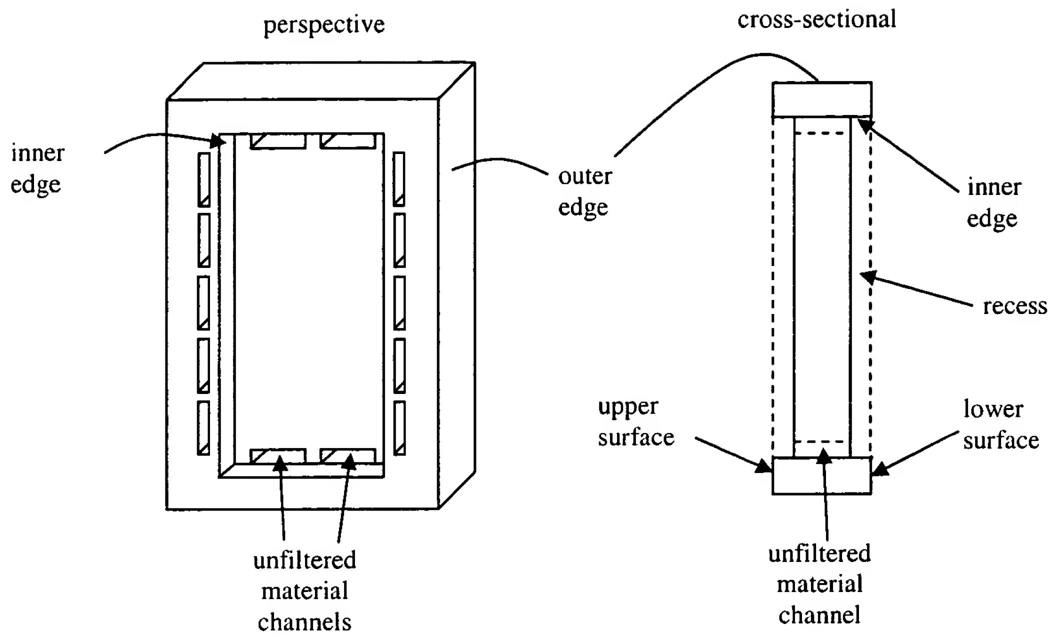
The Examiner is not allowed to arbitrarily pick and choose specific parts of the Karbachsch sealing ring for importation.

Notably, there is no motivation, teaching or suggestion in Karbachsch to import just the outer edge – the inner edge, upper and lower surface are also essential elements of the Karbachsch ring.

Accordingly, considering Karbachsch as a whole, the inner edge, upper surface and lower surface of the sealing ring would also have to be imported into the cassette of Kopf `930.

The net result of this incorporation, based on the Examiner's hypothesized combination, is illustrated below, both as a perspective view and as a cross-sectional view (wherein the cassette is bisected at a location other than the unfiltered material channels).

[2] Of note, the Karbachsch spacers **120** not shown in this schematic for simplicity.



It can be seen that the importation of the Karbachsch inner edge, which MUST correspond to one edge of the unfiltered material channel of Kopf `930 (to be consistent with the teaching of Karbachsch), as well as the Karbachsch upper and lower surfaces, results in the formation of a recess in the Kopf `930 cassette which defines a large, empty volume.

The Examiner is reminded that the Kopf `930 cassettes are arranged in a face-to-face manner and as such, the volume of the modified Kopf `930 cassette recess is actually twice as great as that illustrated in the above figures.

In operation, in addition to passage down the retentate channels of the modified Kopf `930 cassette, the unfiltered liquid will also flow into this expansive recess. The six planes of the recess are defined by gasket material and as such, entrance of unfiltered liquid into the recess does not enhance filtration.

More importantly, it is well known in the art that the cross-sectional area of the unfiltered material channel should be approximately equal to the sum of the areas of the cross flow subchannels so that the pressure drop through the apparatus is suitably low. However, the combination of Karbachsch and Kopf `930, as hypothesized by the Examiner, would result in the passage of the unfiltered material into an **expansive** recess and as such, there would be an

excessively large pressure drop. **This pressure drop would render the Kopf `930 filtration cassette unsatisfactory for its intended purpose and as such, a *prima facie* case of obviousness has not been established**. *See, In re Gordon,* 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984).

Even if Kopf `930 and Karbachsch were combinable, which they are not, the combination of Kopf `930 and Karbachsch would still fail to teach or suggest every limitation of applicant's claimed invention.

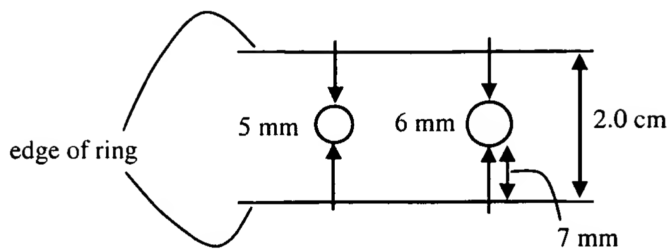
Claim 1 recites, *inter alia*:

> **"wherein said thin gasket layer has a thickness in a range of from about 0.01 inch to not more than 0.3 inch . . . ."**

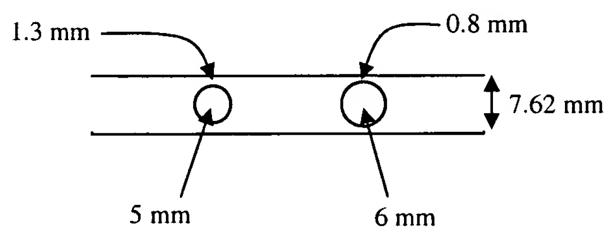
As introduced hereinabove, the sealing ring of Karbachsch is "generally approximately 2 cm wide." The 2 cm wide ring accommodates the 5-6 mm wide filtrate channels, which ensures that the filtrate channels maintain their integrity under 4-5 bars of pressure. Clearly, if one were to import the ring of Karbachsch into the cassette of Kopf `930, though there is no suggestion or motivation to do so, the combination still would not embody every limitation of applicant's claimed invention, specifically "a gasket layer having a thickness in a range of from about 0.01 inch to not more than 0.3 inch" that fully encapsulates all outer surfaces of the filtration cassette.

Furthermore, there is no motivation, suggestion or derivative basis in the references to decrease the width of the Karbachsch ring, because if the ring were narrowed, e.g., to the thickness of applicant's claimed invention, the Karbachsch ring would be rendered unsatisfactory for its intended purpose.

For example, referring to the schematic below, drawn to a 1:1 scale, it can be seen that when the width of the ring is 2 cm (as taught by Karbachsch), the thickness of the wall at the filtrate channel is at least 7 mm (corresponding to a 5-6 mm filtrate channel as taught by Karbachsch).



However, referring to the next schematic, also drawn to a 1:1 scale, if the width of the Karbachsch ring were narrowed, e.g., to not more than 0.3 inch (7.62 mm), it can be seen that the thickness of the wall at the 6 mm and 5 mm filtrate channel is 0.8 mm and 1.3 mm, respectively. Such a thin wall at the filtrate channels would not be able to withstand the disclosed operating pressures (4-5 bar) of the Karbachsch apparatus, and thus the ring would fail.



As such, Karbachsch, and the hypothetical combination of Kopf `930 and Karbachsch, do not motivate, teach or suggest a thin gasket layer having "a thickness in a range of from about 0.01 inch to not more than 0.3 inch" that "fully encapsulates all outer surfaces of said filtration cassette," as claimed by applicant herein.

Lastly, the Examiner is reminded that it is improper to combine references where the references teach away from their combination. *See, e.g., In re Grasselli*, 218 U.S.P.Q. 769, 779 (Fed. Cir. 1983).

Importantly, Karbachsch teaches away from the filtration system of Kopf `930. While discussing the state of the art at the time of filing, Karbachsch discusses the disadvantages of using clamping bolts to combine filtration units, for example:

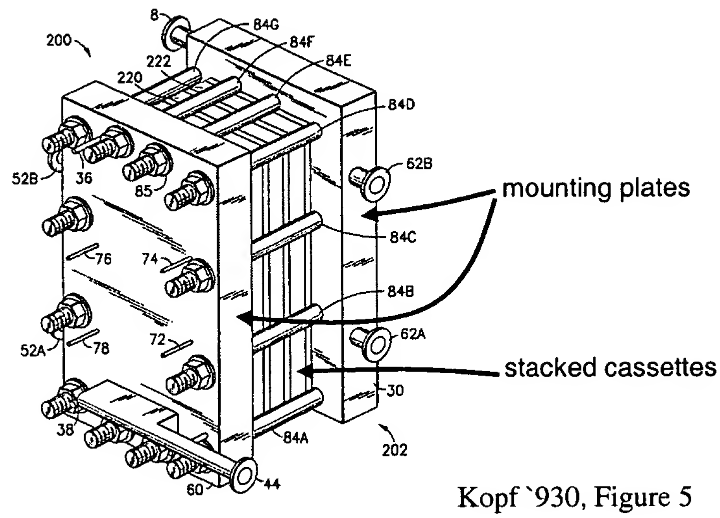
> "In the case of DE-OS 31 27 548 incompressible supporting plates with channel grooves and apertures are premounted alternately with membrane filter units which are sealed at the

> edge side, to form a stack, and a free-flowing sealing agent is injected into the communicating sealing grooves and channels, which agent hardens in the compressed stack and in this way firmly combines it to form a stable box.
>
> . . .
>
> The boxes produced in this manner are altogether incompressible and <u>in a **disadvantageous** manner are additionally clamped between casing plates with main connections by means of a plurality of clamping bolts which have to be tightened by means of torque wrenches</u>." (see Karbachsch, col. 3, lines 9-33) (emphasis added)

In addition, Karbachsch states:

> "A third group of documents, DE-OS 33 17 517 and DE-PS 35 07 908, deals with similar separating devices, wherein the prefabricated membrane pads are stacked on top of one another, separated by a spacer.
>
> . . . The entire stack is disposed in an external plastics material casing and is <u>fastened by screws</u>. . . . Apart from <u>sealing **problems** which occur in the filtrate channel when the stack is compressed by two rods</u>, in this case the membrane pads are pushed apart at the sides, which leads to an irregular flow." (see Karbachsch, col. 3, lines 34-48) (emphasis added)

By contrast, the filtration cassettes of Kopf `930 are constructed to be stacked between mounting plates **30** and **60**, and <u>suitably engaged by mechanical fastener means **85** consisting of threaded rods, washers and lock-nuts</u>, as shown in Figure 5 of Kopf `930, reproduced hereinbelow for ease of reference.



Kopf `930, Figure 5

Considering Karbachsch as a whole, which the Examiner is required to do, Karbachsch **teaches away** from compressing the stacked cassettes by mechanical fastener means, as **required** by Kopf `930.

In light of Karbachsch's disparaging disclosure, where is the motivation or suggestion in either of the cited references to combine the teaching of Kopf `930, which **requires** compression using mechanical fasteners, with Karbachsch, which **disparages** the use of mechanical fasteners? Clearly, one skilled in the art would not combine Karbachsch with Kopf `930.

In sum, there is no basis in the hypothetical combination of Kopf '930 with Karbachsch for applicant's claimed invention. Kopf `930 would be rendered inoperable upon combination with Karbachsch. Further, the combination of Kopf `930 and Karbachsch fails to embody every limitation of applicant's claimed invention. Still further, Karbachsch teaches away from Kopf `930.

The Examiner therefore is respectfully requested to withdraw the rejection of claims 1, 3-7, 10-13, 16 and 19 under 35 U.S.C. §103(a) based on Kopf `930 in view of Karbachsch.

CONCLUSION

Based on the foregoing remarks, claims 1, 3-7, 10-13, 16 and 19 are now in form and condition for allowance. The Examiner therefore is respectfully requested to reconsider and allow such claims.

Respectfully submitted,

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Membrane technology

Membrane systems can be managed either through dead-end filtration or through cross-flow filtration.

Dead-end filtration

When dead-end filtration takes place, all the water that enters the membrane surface is pressed through the membrane. Some solids and components will stay behind on the membrane while water flows through. This depends on the pore size of the membrane. Consequentially, the water will experience a greater resistance to passing through the membrane. When feed water pressure is continual, this will result in a decreasing flux. After a certain amount of time the flux has decreased to such an extent, that the membrane will need cleaning.

Dead-end management is applied because the energy loss is less than when one applies a cross-flow filtration. This is because all energy enters the water that actually passed the membrane. The pressure that is needed to press water through a membrane is called Trans Membrane Pressure (TMP).

The TMP is defined as the pressure gradient of the membrane, or the average feed pressure minus the permeate pressure. The feed pressure is often measured at the initial point of a membrane module. However, this pressure does not equal the average feed pressure, because the flow through a membrane will cause hydraulic pressure losses.

During cleaning of a membrane, components are removed hydraulically, chemically or physically. When the cleaning process is performed, a module is temporarily out of order. As a result, dead-end management is a discontinuous process.
The length of time that a module performs filtration is called filtration time and the length of time that a module is cleaned is called cleaning time. In practise one always tries to make filtration time last as long as possible, and apply the lowest possible cleaning time.
When a membrane is cleaned with permeate, it does not have a continuous production of water. This results in a lower production. The factor that indicates the amount of production is called recovery.

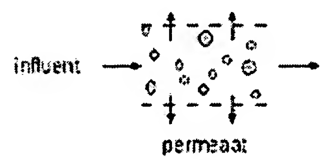
Dead-end filtration

Cross-flow filtration

When cross-flow filtration takes place, feed water is recycled. During recirculation the feed water flow is parallel to the membrane. Only a small part of the feed water is used for permeate

production, the largest part will leave the module. Consequentially, cross-flow filtration has a high energy cost. After all, the entire feed water flow needs to be brought under pressure.

The water speed of the feed water flow parallel to the membrane is relatively high. The purpose of this flow is the control of the thickness of the cake.
Consequentially to the flow speed of the water, flowing forces are high, which enables the suspended solids to be carried away in the water flow.
Cross-flow management can achieve stable fluxes. Still, the cleaning of cross-flow installations needs to be applied from time to time. Cleaning is performed by means of backward flushing or chemical cleaning.
The cross-flow system is applied for Reverse Osmosis, nano filtration, ultra filtration and micro filtration, depending on the pore size of the membrane.



Cross-flow filtration

Membrane technology

[Home] [Back] [More Info]

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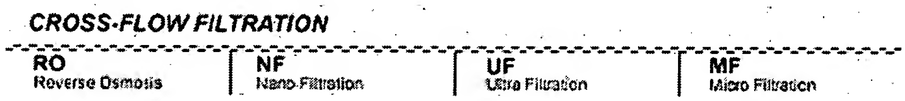
The Cross-flow Membrane Filtration Technique

Generally speaking, a filtration process is a physical separation of matter, which takes place across a semi-permeable media using a pressure gradient.

Filtration can be divided into two groups: Normal filtration, also called "dead-end" filtration, and cross-flow filtration.

By classical dead-end filtration, such as press filter, rotary vacuum filter etc., there is only limited movement in the liquid. The process results in a filter cake which must be removed by mechanical force.

By cross-flow membrane filtration the formation of a filter cake is prevented by a fast flow of liquid parallel to a membrane, which is installed in a channel system. Not only the velocity, but also the membrane characteristics and the flow profile in the membrane channels are of great importance to the result.

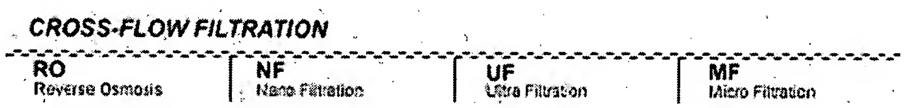


Cross flow-filtration can be divided into four groups:

Reverse Osmosis and Nanofiltration

The reverse osmosis (**RO**) process allows only water and similar small molecules to pass through the membrane. It is used for desalination of water streams and for water removal processes or concentration where it in many instances can substitute an evaporation process.

The nanofiltration (**NF**) process is similar to the RO process, however, a more open membrane is used allowing low molecular weight material to pass through the membrane. This operation is used to perform demineralization and concentration in one step in order to remove salts from different solutions and to concentrate simultaneously.



Ultrafiltration and Microfiltration

Ultrafiltration (**UF**) operates with a more open membrane than both RO and NF. The membranes used for the UF-process are defined by their ability to withhold molecules of certain sizes from a few thousands up to hundreds of thousands in molecular weight (MW). Depending on the MW size, the actual UF membrane is able to reject large molecules such as protein and polysaccharides. These membranes are widely used within the pharmaceutical industry and in the food industry for concentration of milk, whey, eggs, gelatin, gums, etc.

Separation of Nano-sized Naturally Occurring Particles by Cross-Flow Electro-Filtration Process

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Abstract: The major propose of this research is to use surface property of colloidal particle, namely surface charge, for the separation of nano-size particle. Further improvement of the separation efficiency of nano-size colloids can be made by the application of an appropriate electrostatic field. In the presence of an electrostatic field, the particles are collected on the surface of a counter-charged electrode. Base on this concept, we have designed and constructed a prototype cross-flow electro-filtration system (CFEF). Model colloid particle, γ-Al_2O_3 and one naturally occurring colloid particle collected from well water were used to evaluate the performance of the CFEF. Results indicated that the prototype CFEF unit functions properly. There is no clogging problem encountered and there is no need to backwash the CFEF unit under the experimental conditions of this study: The removal rate of nano-sized colloidal particle increases as the applied electrostatic field strength increases. It is possible to effectively separate the nano-sized colloidal particles by adjusting the electrostatic field strength of the CFEF unit.

Keywords: cross-flow, electrofiltration, separation, nano-sized particles, γ-Al_2O_3

Introduction

Separation of nano-sized particles from liquid medium by conventional technique such as filtration is difficult because of their small size. By flow pattern, filtration process can be divided into two major types: dead-end and cross-flow. In the dead-end filtration mode, both the water (flux or permeate, or filtrate) and the solid (or rejection) pass through a filter medium (or membrane) in the same direction. The significant flux declines with the time due to membrane fouling is a potential limitation to the efficient use of dead-end filtration (Iritani, Mukai and Kiyotomo, 2000). In the cross-flow filtration mode, the feed water and the filtrate passes the membrane in a different direction; generally, at almost a right angle. The cross-flow filtration has the intrinsic merit of minimizing the solid contact with the filter membrane. However, since the particles of interest are of the micron or nano-size, further improvement of solid separation efficiency can be made by the application of an electrostatic field. In the presence of an electrostatic field, the particles are collected on the surface of an electrode, usually an anode, as most particulate in water are negatively charged.

Manegolg was the first to study the process of combining conventional pressure filtration and electrophoresis (Manegold, 1937). It was not until 1977 when Henry provided a fundamental analysis of the cross-flow electro-filtration process (Henry, Lawler and Kuo, 1977). Moulik applied an electrostatic field to microfilters and reported excellent removal of colloidal particles such as bentonite and algal cells (Moulik, 1976). Archer et al. designed an electrode capable of generating non-uniform electrostatic fields over a large surface area to separate yeast cells from water (Archer et al., 1993). They reported that a linear relationship between dielectrophoretic collection and pulse length over the range of 0 to 100 sec. Lo et al. separated Al_2O_3 colloids from non-aqueous solution using cross-flow electro-filtration process (Lo, Gidaspow and Wasan, 1983). The effect of feed rate, driving pressure, and electrostatic field strength on the filtration rate and total solid deposition rate on the collection electrode was evaluated. Results indicate that the extent of filter fouling is greatly decreased. Majmudar and Manohar reported the separation of TiO_2 from aqueous solution by electrophoretic filtration (Majmudar and Manohar, 1994). Experiments were carried out at different voltages and flow rates. It was observed that a maximum separation of 96% occurred at 15 V and 200mL/h flow rate. Wakeman and Sabri reported that direct current electrostatic field reduce cake formation in cross-flow membrane filtration (Wakeman and Sabri, 1995). Operating parameters such as filtration pressure, cross-flow velocity, electrostatic field gradient, pH and feed concentration can affect filter performance. Verdegan studied the separation of fine particles (<10 μm) from nonpolar liquids by cross-flow electro-filtration process and reported that cross-flow electro-filtration has many distinct advantages over conventional separation processes such as high removal for all particle size, long life, and minimal power requirement (Verdegan, 1986). Akay and Wakeman reported enchanced removal of a double chain cationic surfactant (diocatadecyldimethylammonium chloride) in water using the cross-flow electro-filtration process (Akay and Wakeman, 1996). Wakeman reported electrophoretically assisted cross-flow microfiltration of bovine serum albumin (BSA), ovalbumin and denatured lactalbumin (Wakeman, 1998). It is shown that the steady state flux is higher when an electrostatic field is applied than it is with conventional cross-flow microfiltration. The flux is almost independent of the membrane pore size. Finer pore sizes enable steady state flux and rejection condition conditions to be reached sooner.

Von Zumbusch et al. reported that the alternating electrostatic field diminished membrane fouling and hence yields a higher specific filtrate flux

LECTURE 10

ADVANCED TREATMENT PROCESSES

MEMBRANE PROCESSES

Membrane is defined as intervening phase separating two phases forming active or passive barrier to the transport of matter. Membrane processes can be operated as: (1) Dead-end filtration; and (2) Cross-flow filtration.

Dead-end filtration: it is the filtration at one end. However, the problem with these systems is frequent membrane clogging.

Cross-flow filtration: Overcomes the membrane clogging and widely used in water and wastewater treatment.

The clean water flux across a membrane without any materials being deposited, is given by Darcey's Law:
$J_w = \Delta P/\mu R_m$

Net pressure across a membrane considering the osmotic pressure is given by ($\Delta P - \Delta\Pi$), thus the equation for the permeate flus is given by:
$J_w = (\Delta P - \Delta\Pi)/\mu R_m$

where,
$\Delta\Pi$ = osmotic pressure, N/m^2

Once the filtration is started, the internal surface of the membrnae gets quoted with the particles, thus offering additional esistance to the filtraiton. Thus the above equation can be modified to include cake resistance:

$$J_w = (\Delta P - \Delta\Pi)/(\mu(R_m + R_c))$$

where,
J_w = permeate flux, m/s
ΔP = pressure difference, N/m^2
R_m = internal membrane resistance, 1/m
R_c = resistance due to deposit on surface, 1/m